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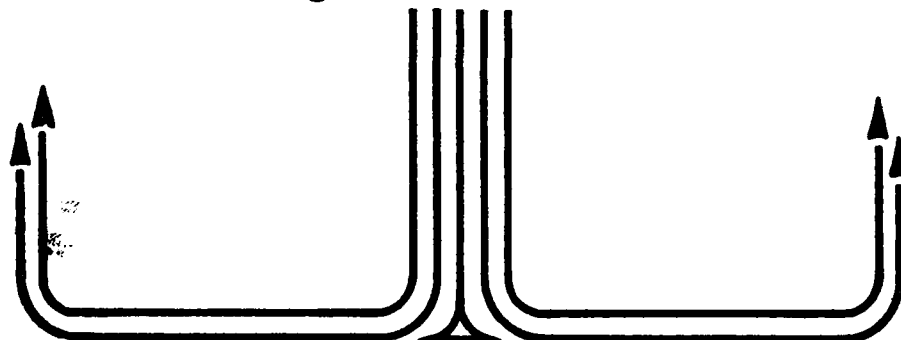
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## STUDENT REPORT

AIR FORCE SYSTEMS COMMAND SOFTWARE  
INDEPENDENT VERIFICATION AND VALIDATION  
IMPLEMENTATION ANALYSIS AND GUIDANCE

MAJOR RICHARD S. BUTLER 88-0430

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AIR FORCE SYSTEMS COMMAND SOFTWARE INDEPENDENT  
VERIFICATION AND VALIDATION IMPLEMENTATION ANALYSIS  
AND GUIDANCE

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<p>Software Independent Verification and Validation (IV &amp; V) implementation across AFSC is varied. These variances cause non-uniform application of IV &amp; V even when applied with common software development practices. The analysis shows that IV &amp; V is being implemented within the intent of the governing regulation and standards. However, there is a need for common guidance for IV &amp; V use. The study presents two levels of guidance; one for contracting and one for management oversight within AFSC. The expected results are improved IV &amp; V use when integrated with common development practices. This should improve systems that depend on software as a key element.</p>					
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## PREFACE

Software Independent Verification and Validation (IV & V) provides objective evaluations of computer software. In Air Force Systems Command (AFSC) these evaluations encompass software design, development, and production phases. The phases correlate to the associated hardware phases and when integrated produce an operational system. As more systems incorporate software to perform critical functions, software becomes the force multiplier. Without evaluations software products may not work properly with the required hardware, lowering system effectiveness. Software IV & V provides an avenue that evaluates the software independent of the original software developer. These evaluations provide a measure of assurance that the software will perform or support the required mission or hardware.

A majority of projects in AFSC implement software IV & V. However, the various IV & V implementations do not follow a common approach. Therefore, each IV & V implementation requires review to ensure adherence to regulations, annotate any concerns, and provide guidance if additional software IV & V direction is required for a common approach.

The author wishes to thank Air Force Systems Command, Mission Critical Computer Resources (MCCR) Directorate for their support and guidance on this project. A thank you is also directed at the AFSC product division's Computer Resource Focal Points (CRFP) and Joint Logistics Commanders, Joint Policy Coordinating Group on Computer Resource Management. Without these offices' inputs and guidance this paper would not be possible.

The recommendations proposed in this paper are intended for application across AFSC. The implementation of the recommendations should be through a coordinated effort by Headquarters AFSC MCCR Directorate, AFSC CRFPs, and the AFSC Inspector General.

## ABOUT THE AUTHOR

Major Butler is currently a student at Air Command and Staff College, Maxwell AFB, Alabama. His previous assignment was at Headquarters Air Force Systems Command, Mission Critical Computer Resources Directorate. During the tour at the headquarters, he supported development and publication of DOD-STD-2167, Defense System Software Development. In addition, he managed the development of the software quality area, being developed into DOD-STD-2168, Defense System Software Quality Program. Major Butler has lectured at Defense Systems Management College and numerous technical symposiums throughout the United States. He co-authored the technical paper "DOD Develops Single Set of Software Quality Standards." His prior experience includes Chairman, Joint Logistics Commanders, Computer Software Management Subgroup, Deputy Project Manager for joint service Computerized Adaptive Testing project, and Program Manager for Digital Integrating Subsystem. Major Butler has been actively involved in the development and acquisition of Air Force mission critical computer resources for over 12 years. He holds a Master of Science in Management Science degree and a Bachelor of Science in Electrical Engineering degree. Additionally, Major Butler completed the Program Managers Course at Defense Systems Management College.

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## EXECUTIVE SUMMARY

Part of our College mission is distribution of the students' problem solving products to DoD sponsors and other interested agencies to enhance insight into contemporary, defense related issues. While the College has accepted this product as meeting academic requirements for graduation, the views and opinions expressed or implied are solely those of the author and should not be construed as carrying official sanction.

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REPORT NUMBER 88 - 0430

AUTHOR(S) MAJOR RICHARD S. BUTLER, USAF

TITLE AIR FORCE SYSTEMS COMMAND SOFTWARE INDEPENDENT  
VERIFICATION AND VALIDATION IMPLEMENTATION ANALYSIS  
AND GUIDANCE

I. Purpose: To review various implementations of software Independent Verification and Validation (IV & V) across Air Force Systems Command (AFSC). The review will evaluate the implementations against established direction and propose, if required, alternatives or improvements to the direction.

II. Problem: Software IV & V across AFSC is implemented based on past experiences and appears to deviate from established direction. The review needs to assess these departures and determine what common concerns, guidance or enhanced directions are required.

III. Analysis: There are six product divisions within AFSC that implement or support software IV & V. In addition, Air Force Logistics Command supports software IV & V requirements on fielded systems. The analysis reviews the respective IV & V implementations and support actions against established direction. Also, the particular rationale for each application is reviewed. As a result 10 issues are identified that concern effective IV & V implementation. These 10 issues are grouped into two Categories. Category I concerns lack of common software IV & V guidance. Category II discusses the



## EXECUTIVE SUMMARY CONTINUED

need to obtain IV & V data in developing policy which is controllable from a central office.

IV. Findings: Each AFSC and support area follows the intent of the IV & V direction. However, a need exists for common guidance to bridge the gap between direction and application. This provides an ability to concurrently initiate an IV & V effort with the software development effort. By applying IV & V guidance early, software projects may avoid problems later on. To keep guidance effective for AFSC a central office is needed. The office can also direct that IV & V be considered for projects early. This consideration happens when there is direction, time, and money. A central office using feedback from associated AFSC areas establishes interaction among the product divisions and ability to develop IV & V guidance that is supportive of the field.

V. Conclusion: A common set of guidelines for Category I issues are developed. The guidance covers three elements; general, development contractor, and IV & V agent. This way the Government, prime contractor, and software IV & V agent are all involved. The IV & V guidance is a layered approach, with each element addressing issues for effective IV & V interaction and evaluation. To support Category II issues, four tools are outlined that link guidance/policy to field inputs and feedback. The tools provide the data base, field concerns, and outside evaluations that allow policy to reflect appropriate needs. Drawn together, the guidance and tools provide a cohesive software package that supports IV & V implementations across AFSC.

VI. Recommendations: Through application of the guidance and tools, AFSC starts towards a standard software IV & V implementation. The process starts with initial guidance, allowing the AFSC areas to improve the guidance with headquarters interaction, not interference. The improvements are developed using existing avenues developed for each tool. This closes the loop, allowing software IV & V to be implemented, evaluated, enhanced, and reimplemented.

## Chapter One

### SOFTWARE INDEPENDENT VERIFICATION AND VALIDATION (IV & V) BACKGROUND

#### INTRODUCTION

Software Independent Verification and Validation is a practice which presents an evaluation of software products apart from the original developer's evaluation. The practice involves a variety of techniques which evaluate the software. This paper will not debate the techniques employed. The purpose is to review software IV & V policies, activities, and implementations across Air Force Systems Command (AFSC). These policies will then be assessed against AFSC implementations for inconsistencies and concerns that may require new or updated policies. If any concerns are noted, they will be evaluated for common applicability across AFSC; along with specific recommendations for software IV & V, in terms of policy formulation and common implementations, if applicable.

The intended audience for this paper is the Air Force Systems Command, Mission Critical Computer Resources (MCCR) activities. These activities are located throughout AFSC at the product division, headquarters, and inspector general field offices. Their responsibilities are to apply, direct and evaluate MCCR requirements on programs. The MCCR primary objective is to satisfy the system level or software specific requirements. One avenue supporting this objective is the application of software IV & V to AFSC programs.

#### PROBLEM

Implementation of software IV & V among AFSC product divisions varies. (27:--;28:--;29:--;30:--;31:--) This variance requires review to ensure that implementations comply with prescribed regulations and support field requirements. Additionally, common areas of concern across the various implementations require identification. These common areas require evaluation to determine if a common set of software IV & V guidance or requirements can be developed and applied across AFSC implementations.

## PREVIOUS STUDIES

Two studies performed in 1981 and 1983 addressed how software IV & V affected programs. Each study presented recommendations to improve software products through the use of IV & V. These studies became the foundation for developing software IV & V direction.

In 1981 Rome Air Development Center (RADC) examined the effects of IV & V on software reliability, maintainability, development cost, and development productivity. Major conclusions and recommendations are:

1. IV & V significantly improves software reliability. (4:39)
2. Cost benefits of IV & V are enhanced by early detection of problems. (4:89,100)
3. IV & V should be used early to detect problems and ensure that corrections are reverified. (4:4,39)
4. Begin IV & V early in the development process and require delivery of preliminary development materials. (4:80)

The Joint Logistics Commanders Joint Policy Coordinating Group on Computer Resource Management (JLC-JPCG-CRM) hosted an Orlando I workshop in November 1983, entitled Post Deployment Software Support (PDSS) for Mission-Critical Computer Software. IV & V was addressed by the workshop and the findings included:

1. "IV & V can and should be used in all phases of the software development cycle." (1:2-5)
2. "IV & V can be performed "in house" or with a separate contractor as long as the IV & V agent is independent of the developer." (1:2-6)
3. Develop a policy that directs the program managers to determine the extent of IV & V effort to be used on their programs. (1:2-7)
4. A program manager's guidebook is needed to determine the level and cost/benefit of IV & V for a program. Also, what IV & V specifics should be accomplished during various phases of the life cycle. (1:2-7)

### INTERIM CONCLUSION

The key conclusion is that IV & V does improve the final software product. The improvement is beneficial when IV & V is initiated early, before the design is firmly established. (4:39,80) Therefore, a policy is required to consider IV & V implementation early in a project to support early detection of errors. In addition, software guidance is needed to implement IV & V effectively. (4:100;1:2-7) These two recommendations are initiated in the current IV & V related regulation and standards reviewed in Chapter Two.

## Chapter Two

### CURRENT DIRECTION FOR SOFTWARE IV & V

The recommendations in Chapter One provided the baseline for current IV & V direction. This direction is contained in three documents which address application and implementation of IV & V for software. The documents are AFR 800-14, DOD-STD-2167, and DOD-STD-2168 (Draft). In addition, the JLC-JPCG-CRM is developing a guidebook for software IV & V applications for program managers. These documents are discussed below.

#### AFR 800-14

AFR 800-14, Lifecycle Management of Computer Resources in Systems, is the dominant regulation for software development within Air Force Systems Command. The regulation recommends early use of software IV & V to detect problems. The key points are: traceability of requirements, evaluations, and testing. These points are noted in IV & V definitions and specifics and form the common base of understanding for the application of IV & V in the software standards.

#### Definitions

"Verification is an evaluation at the Computer Software Configuration Item (CSCI) level to determine whether the products of each step in the software development cycle fulfill all requirements from the previous step." (2:21) Verification is initiated as early as possible, normally during the requirements analysis stage, to ensure requirements are properly documented and understood. The process involves code analysis, evaluations of documents, traceability matrices, and software component level testing to ensure lower level requirements are properly designed. (2:21)

"Validation is the evaluation and testing activities at system level to determine compliance of the final CSCI product with the system requirements." (2:21) The activity covers actual testing of code against a set of requirements or situations involving the system. Documentation evaluation and traceability are continued against the evolving code and system level integration requirements.

#### IV & V Specifics

The program manager will consider using IV & V based on recommendations from the Computer Resources Working Group (CRWG). The recommendations are documented in the Computer Resources Life Cycle Management Plan (CRLCMP). (2:7) The CRLCMP, as outlined in AFR 800-14 requires the level, scope, and source of IV & V described within the quality section, paragraph 8g, of the CRLCMP. (2:44) In addition, four key areas supporting the implementation of IV & V for software require addressing.

1. First preference for an IV & V agent should go to the organization supporting the software, provided the required skills and resources are available. In any case, the IV & V agency should be separate from the developing agency, to avoid conflicts in the independent evaluation. (2:7)

2. The statement of work (SOW) for the developer will require granting the IV & V contractor access to the software development products (code and documents). In addition, any applicable engineering environments for the various levels of testing and integration tasks will be made available. (2:10) Without key documents and software environments the IV & V agent will not be able to evaluate and/or test designs adequately.

3. Air Force Operational Test and Evaluation Center (AFOTEC) or designated test organization will "determine the scope and nature of software tests for the Operational Test and Evaluation (OT&E)." (2:3) The test organization will provide respective inputs to the Computer Resources Working Group (CRWG) on the use of IV & V. (2:3) Without test inputs based on system requirements the IV & V agent's ability to support testing is reduced. The IV & V agent's review of data helps ensure the OT&E can function as expected.

4. The Air Force Systems Command/Air Force Logistics Command supplement to AFR 800-14 adds further clarification for IV & V planning. The supplement states that IV & V planning will be completed before the Full Scale Development (FSD) Request For Proposal is released. (3:11)

AFR 800-14 establishes the goals of an IV & V effort for software. The goals are implemented through tasking documents. These documents are the standards and contract statements employed on software projects. In particular, the software development standard, DOD-STD-2167 and associated data requirements, are key to an IV & V effort. These documents outline the requirements traceability, evaluations, and testing for software products.

DOD-STD-2167, -2168 (DRAFT)

DOD-STD-2167, Defense System Software Development, 4 June 1985, covers the entire software development process from concept to production. The standard directs the developer to coordinate with associated contractors, e.g., software IV & V agent. (5:20) DOD-STD-2167A (Draft, 1 April 1987) addresses the interface with the software IV & V contractor and how the developer will support the interface. (21:11) This tasking between the developer and IV & V agent is important. It initiates the framework under which the products and processes are obtained and evaluated. Without early establishment of responsibilities, a change later in the contract may cause cost and schedule overruns.

DOD-STD-2168 (Draft, 1 April 1987), Defense System Software Quality Program, parallels the development standard on application of the quality evaluations during each phase of the development process. In particular, DOD-STD-2168 supports DOD-STD-2167A (Draft) on interfacing with the IV & V agent and requires evaluations of the corrective action system under the software quality program. (23:4) The corrective action system is where IV & V inputs are tracked by the developer and Government. This system supports RADC's recommendation of verifying corrections have been made.

DI-MCCR-80030, Software Development Plan (SDP), Data Item Description tasked from DOD-STD-2167, is a key player in the software development process. The SDP outlines the overall software design objectives and means. It requires the developer to document, in part, the interface with the IV & V agent and discuss the corrective action system. (18:5,6) By including IV & V data, the SDP becomes a prime management document for the developer, Government, and IV & V agent.

Through contract statements, interactions between standards and data items are specified. Without the statements, the ability to tailor specifics of the standards and related data items for various applications is lost. They also outline what additional requirements are needed to ensure the Government acquires the correct products. This is the link that ties standards and data items to the IV & V effort. Without contract statements, the prime developer will not know the interactions required to support IV & V tasks.

### IV & V GUIDEBOOK

The IV & V guidebook is currently under development by the JLC-JPCG-CRM. The guidebook is to become a tool for program managers to use in determining the extent of IV & V application for projects. Future sections may outline SOW descriptions that could aid a program manager in structuring a contract. (17:1-1) As noted above, contract statements are avenues for proper IV & V tasking. Without guidance to program managers, that tasking may not exist.

### INTERIM CONCLUSION

The initial studies reflected a need to exert software IV & V early in software development projects. The purpose is to detect problems early before they become designed into the software. The regulation and standards established IV & V as a process supporting early evaluation of software designs. The correlation of the design and IV & V process are derived from the contractual statements. The key task is to derive specific applications of software development and quality for the particular IV & V implementation. The guidebook is one avenue being explored now by the JLC-JPCG-CRM. However, the guidebook is in draft and currently does not contain guidance for software IV & V tasking within statements of work (SOW). The intent of the IV & V direction and applicable standards is to establish an early link between development and evaluation of the software. The next chapter presents how this link is implemented by various AFSC product divisions.



## Chapter Three

### CURRENT IMPLEMENTATIONS

The previous chapters outlined the problem and directions currently established for software IV & V. The regulation, standards, and draft guidebook provide initial references for the program manager. However, program managers lack clear guidance on SOW tasking for IV & V implementations. To better evaluate this lack of guidance, a review of AFSC product division's software IV & V implementation is needed. This chapter will establish whether the various IV & V approaches are following the intent of existing direction specified in Chapter Two. A secondary outcome is the determination if additional policy or set of common IV & V requirements are warranted.

### INTERVIEWS

The following data was collected from the Mission-Critical Computer Resource (MCCR) Focal Points in the respective AFSC product divisions. Air Force Logistics Command was also contacted since they support numerous software systems and act as an IV & V agent. The respondents indicated their respective areas are using IV & V on major programs. The extent of and arrangements for IV & V are based on system program office (SPO) decisions (acceptable under AFR 800-14, page 13). The decisions are the result of recommendations provided by the respective MCCR offices. The divisions and AFLC are satisfied with their respective IV & V efforts. However, respondents indicated concerns with certain aspects of their IV & V implementations. Each IV & V implementation and associated concerns are provided below. As appropriate, the respondent's and author's concerns are blocked and identified with issue numbers [ISSUE #]. This allows for grouping the issues and evaluation in the interim summary and follow-on chapters.

#### Aeronautical Systems Division (ASD)

The contracts ASD manages normally employ the prime developer of the software product to perform IV & V related tasks internally. This is allowed under AFR 800-14 page 21, provided that a separate organization, apart from the prime's

development team, performs the required tasks. These tasks and organizational setup are documented in the Software Development Plan delivered under the Request for Proposals (RFP) and contract. (27:--)

This approach directs the prime to document, plan, manage, and execute a verification and validation (V & V) process to ensure stated requirements are met. With the developer documenting the process, the Government can evaluate the proposed effort during contract award and track the actual process after award. This internal V & V process is one element in the ASD software integrity program that seeks to improve operational, supportable, and reliable software in weapon systems. (24:--)

[ISSUE 1] Key among the challenges for ASD is the selection of capable software developers, application of a systematic software engineering process, and development of software within planned program baselines. (27:--)

ASD developed the integrity program to address issues affecting weapon system software. Various systems were being delivered with software errors, inadequate testing, incomplete software, and developed under lax engineering practices. (27:--)

ASD's effort seeks to correct these deficiencies by getting developers to manage and implement improved software development, support, and testing processes. The internal V & V ties the processes together from the initial software requirements phase to final customer acceptance.

ASD pursued an internal V & V approach since previous IV & V results were unsatisfactory. Previously, documents were not totally evaluated, IV & V experience and testing was lacking, and development contractors were relying on IV & V agents to perform the developer's software engineering and quality responsibilities. Since ultimately the developer is responsible for the software product, not the IV & V agent, the onus to deliver quality software and ensure it meets the requirements belongs to the developer.

Internal V & V is recommended by an ASD management team to help new programs utilize the V & V process effectively (this action follows the guidance in AFR 800-14, page 7). The team is composed of experienced software acquisition members who evaluate the critical nature of a program's software, then propose V & V applications and tailoring guidelines to the program office. Independent V & V may be recommended based on the critical level of software; i.e., safety of flight or nuclear essential areas. The team's recommendations are provided to program managers for inclusion within their CRLCMP and SOW. In addition, the team recommends software development specifics for the RFPs, completing the software integrity structure for each program. (27:--)

The ASD approach allows the developer and outside V & V agent to agree on the availability and proprietary nature of any of the development that must be used to properly test and evaluate the software. This last area is critical when considering the competitive edge a software developer wants to maintain. Therein lies the problem of competing software developers performing IV & V on the other's product. The final effect may be higher costs to offset a potential loss of market share to the developer.

[ISSUE 2] Without a contractual understanding between the developer and V & V agent, the agent may gain an unfavorable advantage over the developer on future contracts. (Author's Issue)

[ISSUE 3] There is the possibility the developer will not allow the IV & V agent proper access to key software elements, opening the potential for untested software in the weapon system. (Author's Issue)

Under AFR 800-14, page 10, the agent must have required access to the needed elements. The ASD approach allows the developer to acquire V & V resources internally, while still holding the developer responsible for overall quality and performance of the software. The ASD software V & V implementation follows the intent of the IV & V direction.

#### Electronic Systems Division (ESD)

ESD employs an 8a firm (small disadvantaged business) to provide an "on-call" (available as needed) IV & V capability for ESD program offices. The program offices determine the applicability of IV & V based on recommendations from the CRWG and associated offices within ESD. The program offices using the "on-call" IV & V agent fund their respective portion.  
(30:--)

[ISSUE 4] The ability to determine initial tasking and cost estimating between program office and agent's contract requirements is needed. (Author's Issue)

The "on-call" approach was developed due to IV & V being initiated late in many ESD programs, usually after errors had been detected. The IV & V agent performs documentation and testing as required by program offices. Skill and experience level of the agent is being improved by employing experienced IV & V individuals. ESD meets the intent of the IV & V direction with this approach.

[ISSUE 5] The 13 individuals may be tasked to support multiple ESD programs, limiting their availability to support any one program full time. (Author's Issue)

[ISSUE 6] Since this is a new approach, a survey should be initiated to monitor IV & V implementation, impacts, and improvements in order to determine the utility of the IV & V program. (30:--)

#### Space Division (SD)

SD is using IV & V on major programs such as NAVSTAR, Boost Surveillance Tracking System (BSTS), and Milstar. Each program is using separate IV & V contracts. Each program uses recommendations from their software project manager and computer resource office to implement IV & V. The rationale for separate contracts is that complexity, size, and uniqueness of each program requires an IV & V agent dedicated to the project. (31:--) SD's implementation follows the intent of the IV & V direction.

SD indicated, from their experience, some development contractors rely on IV & V agents to catch problems the developers should have earlier. This allows the developer to meet schedules and worry about product quality later.

[ISSUE 7] To counter the above attitude, improved software management techniques are required in the developer's and IV & V agent's SOW. (31:--)

#### Air Force Contract Management Division (AFCMD)

AFCMD noted that numerous programs they monitor employ IV & V tasks. They discovered certain tasks requested under the auspices of IV & V were really Contract Administration Service (CAS) functions. They resolved the duplications and improved the IV & V/CAS/SPO relationships. (32:--) AFCMD's interaction with IV & V follows the applicable direction. They did raise two issues as a result of the duplication.

[ISSUE 8] AFCMD's primary concern is the contractual implementation of the IV & V task must avoid duplication of effort between Government and IV & V agent. (32:--)

[ISSUE 6.1] A survey of AFSC IV & V efforts could help avoid duplications. The survey should identify IV & V areas used in supporting weapon systems and interactions between the IV & V agent, CAS, and SPO during software development. The results could provide insight on how to structure contracts to gain the best IV & V effort given various circumstances. (32:--) This issue is common to the ESD Issue 6.

### Ballistic Missile Organization (BMO)

BMO uses IV & V on an extensive basis under competitive procurements. Their agents have a working knowledge of past BMO requirements and provide both documentation and testing capabilities. IV & V is mandated on programs. A majority of these programs require nuclear certification; thus, software is evaluated to ensure requirements are correct and met. No concerns were reported. (29:--) BMO follows the intent of the IV & V direction.

[ISSUE 9] A minimum set of IV & V criteria for updating established parameters and projects is essential even under strict requirements. (Author's Issue)

### Armament Division (AD)

AD is implementing IV & V on major programs. The implementation is based on CRWG and computer resource office recommendations to the program offices. The recommendations are forwarded to the SPD for consideration during the development of the FSD Request For Proposals. The Advanced Medium Range Air to Air Missile (AMRAAM) is using the Navy at Point Magu and Air Force at Warner Robins Air Logistics Center as IV & V agents. AD has implemented IV & V on the Training Ranges segment of the Global Positioning System program. In both instances the IV & V effort is reported as satisfactory. (28:--) AD's implementation follows the intent of the IV & V direction.

[ISSUE 10] However, AD focal point noted that IV & V is normally advocated by them, instead of collectively with the using and supporting commands. Therefore, advocacy for IV & V from higher echelons could improve IV & V use. (28:--)

### Air Force Logistics Command (AFLC)

AFLC confirmed that they are providing IV & V support on numerous projects, e.g. B1-B Automatic Test Equipment and F-16A/B Operational Flight Program (OFP). The F-16 IV & V effort on OFPs was successful. The knowledge gained by the IV & V agent (Ogden Air Logistics Center (ALC)) and developer (General Dynamics) allowed each to switch roles; Ogden ALC performs F-16 A/B OFP block updates and General Dynamics is the IV & V agent. (33:--) AFLC follows the direction within AFR 800-14, since they perform IV & V and maintenance roles for various weapon systems. (2:7)

[ISSUE 6.2] AFLC is developing a survey to collect IV & V data concerning AFLC products. (33--) The data could support similar efforts at AFSC and is a companion to ESD Issue 6 and AFCMD Issue 6.1. (Author's Issue)

#### Summary

The review identified ten issues that effect IV & V implementations across AFSC. These issues are grouped under two categories for software IV & V, as summarized in Table 1. Category I involves the availability of specific guidance to the Government, developer, and agent in terms of data, information, and levels of testing that are required for IV & V. Category II involves initiating IV & V early in the program's life cycle. Without early IV & V the ability to detect errors is lost. Early implementation requires an advocate for IV & V. The advocate ensures IV & V is considered at the decision making levels on par with development decisions. The computer resource focal points stated that AFSC is usually the early advocate for IV & V. Therefore, when IV & V is used, it is due in part to the ability of the AFSC computer resource offices and engineers who recommended implementation of IV & V to the program manager. Additionally, a strong advocate, monitoring the IV & V tasking, provides impetus to use and support the additional cost and schedule drivers required to perform IV & V.

#### INTERIM CONCLUSION

Based on the above implementations and governing directions, the AFSC product divisions are implementing IV & V correctly. They recognize IV & V is advantageous and provides the program offices with abilities to improve reliability through detecting problems earlier in the software requirements and code development cycles. Each implementation is within the scope of the rules established under AFR 800-14. As more product divisions begin implementing DOD-STD-2167 on new programs, the respective IV & V tasking will improve, but differently from other divisions. Additional IV & V policy, beyond AFR 800-14's, is not required. What is required is guidance on initial common approaches and a central office for collecting IV & V implementation data and advocating its use.

To provide the initial approach and a central office, the two categories above offer avenues to achieve these needs. Category I concerns various unstructured implementations of software IV & V across AFSC. Even with improved IV & V tasking, as more divisions adopt DOD-STD-2167, there is no direct IV & V guidance. A common set of software IV & V guidance provides a foundation for each product division to

Category I - Specific Guidance for Software IV & V		
Issue #	Division	Issue Explanation
1	ASD	Selection of competent software contractors, following established processes.
2	ASD	Establish understanding between software developer and IV & V agent
3	ASD	Provided required access to materials
4	ESD	Provide "on-call" IV & V assistance.
5	ESD	Support multiple programs with fixed resources.
7	SD	Avoid using IV & V as developer's quality function. Improved software management techniques are required.
8	AFCMD	Implement IV & V correctly on contract, avoid duplication w/AFCMD functions.
9	BMO	IV & V used extensively, no tailoring required.

Category II - Software IV & V Data Collection/Advocacy		
Issue #	Division	Issue Explanation
6	ESD	Survey to monitor effectiveness of "on-call" IV & V agent for ESD
6.1	AFCMD	Identify interactions with parties
6.2	AFLC	Separate survey for IV & V.
7	SD	Improve software management.
10	AD	Maintain software IV & V advocacy.

Table 1. Software Categories/Product Division Issues

initiate their own independent software evaluations. They currently lack a reference that lists the minimum efforts for software IV & V. The guidebook being developed by the JLC-JPCG-CRM may cover these efforts, but is not yet published. (34:--) Therefore, the need for guidance is urgent as more product divisions adopt the software development philosophy of DOD-STD-2167.

Category II covers the requirements for IV & V data collection and tracking to ensure proper implementation. The data would provide an assessment of IV & V policy and tactics to the central office. This office serves as the central focal point for developing a coordinated policy and as the advocate for IV & V. This in turn, provides product divisions a central authority on policy that works with field users to promote positive effects of IV & V policy and application. The next chapter outlines each category's issues and solutions.



## Chapter Four

### COMMON SOFTWARE IV & V REQUIREMENTS

Chapter Three reviewed various IV & V implementations across AFSC Product Divisions. The review concludes that each implementation is following the intent of the governing regulations. However, 10 issues surfaced that concern IV & V implementations. Those issues fall within one of two categories, summarized in Table 1. The issues do not violate the governing regulation, so the need for additional regulations is not warranted. What is necessary is common guidance and support for software IV & V. Therefore, an evaluation of each category, associated issues, and recommended solution for IV & V guidance and support is provided below.

Category I covers those issues needing guidance on the application of software IV & V for programs. Category II covers those issues involving the collection of data and support for IV & V across AFSC. Category evaluations are based on numerous sources and the authors 12 years of software related acquisition experience, which included experience in the drafting of DOD-STDs-2167, -2167A (Draft), -2168 (Draft) and associated policies.

#### CATEGORY I SOFTWARE IV & V GUIDANCE

Category I addresses the need for sufficient guidance to allow product divisions to initiate IV & V efforts early to support a program's development effort. Issues from five product divisions addressed this need, as outlined in Table 1. These issues are evaluated below along with a proposed solution for Category I.

The Category I dilemma is; to initiate IV & V efforts early requires the product divisions to know IV & V requirements for the software development project being proposed. This forces program offices to understand software and hardware interrelationships within the development effort before they are developed. Knowing interrelationships beforehand is difficult, resulting in unknown requirements surfacing and effecting contracts, schedules, and performance

in a negative manner. However, a minimal set of IV & V requirements can establish the ground work for both the developer's and IV & V agent's proposals and designs. Without established requirements in the RFP, IV & V tasks lag the development effort causing probable delays in the end product. The developer will in turn be told, after development starts, what is expected in terms of IV & V support, leading to additional cost and schedule factors that in all probability were not accounted for in the winning proposal.

#### Product Division Issues

There are eight issues that comprise Category I. Each issue has concerns requiring satisfaction before the particular division can better implement software IV & V. A common theme, among the issues, is the availability of guidance to improve IV & V implementation. The discussion below outlines the issue's requirements to improve the implementation and type of guidance required.

ASD Issues 1, 2, and 3. Aeronautical Systems Division's issues require specific guidance in order to ensure their products are adequately assessed. The guidance should cover either an internal (developer) or external IV & V agent. An evaluation of these issues is presented below.

Issue 1. ASD needs to ensure software developers are capable, are using systematic software engineering processes (DOD-STD-2167), and the development is within established baselines. Without initial guidance the possibilities of inconsistencies between the development contract and IV & V effort will develop. As a result, the probability of evaluating outdated products, documents or out of scope requirements increases. Guidance on IV & V interactions between the developer and IV & V agent could lower the probability of inconsistencies and improve the engineering process.

In contracts, the developer must indicate the relationships with any outside contractor or requirements. If a common set of software development related IV & V requirements are provided, the developer's reply will indicate his understanding of the engineering processes and interactions required. An IV & V set aimed at the developer provides initial data allowing the program offices to determine if developers are capable of performing software development and IV & V efforts as applicable.

Issue 2. In conjunction with Issue 1, the second concern is the understanding between the developer and IV & V agent. This understanding is the contractual language that

directs each party to provide specific information to the other without threat of competition. Issue 1 involves providing the developer with initial IV & V guidance so the program office could adequately evaluate the proposal. In turn, the IV & V agent(s) require a common set of tasks for their evaluation and response to parallel the developer's during the same period. Without these common tasks, the agent is still evaluating his response while the development is into critical design. Therefore, to ensure the IV & V agent is on-line with the development schedule, a common set of IV & V requirements, established early, are required. Without coordinated contractual efforts, between developer and agent, assumptions are made on responsibilities and relationships. A concurrent set of IV & V agent tasks specify the initial relationships and responsibilities. This allows the Government, developer, and agent to coordinate during contract formulation on what is expected. This helps in avoiding conflicts of interest. The added benefit provides the ability to cross check requirements. Thereby, avoiding tasking the agent to check a function that is not required or proprietary.

Issue 3. The final issue concerns access to required materials. The developer and agent must have access to the other's materials, as contractually specified. This must be dealt with up front in each contract. By providing guidance on initial IV & V and development interactions, each contractual party can propose guidelines for release of materials, schedules, and cost for the access. This allows the Government the ability to evaluate the responses to ensure that required access is available, requested, and does not duplicate existing resources available to the program office.

ESD Issues 4 and 5. Electronic Systems Division's issues require review to ensure "on-call" resources are efficiently employed. General guidance on how program offices integrate the resources within the programs is required. This allows ESD to fully utilize the "on-call" capabilities of the IV & V agent. The following discussion outlines the concerns.

Issue 4. ESD uses an "on-call" IV & V agent for use across ESD programs. Each program office determines the utility of using the agent, within the confines of the agents contract. Since each office funds their use of the agent, they require an initial estimate of the cost. Common guidance for IV & V tasking could provide initial estimates. Common guidance provides the ability to enhance or tailor out specific tasks. This approach allows improved cost estimates since the agent's overall contract contains related costs for tasks and man-hours. (30:--)

Issue 5. An "on-call" IV & V agent for ESD presents a serious problem. With only a limited number of personnel the agent may not spend sufficient time on all IV & V tasking. This requires the program offices and ESD MCCR focal point to ensure tasks are adequately covered. If not, then additional manpower, separate contracts, or elimination of IV & V tasks are required. Without an initial set of requirements, the agent may be tasked with a larger role than is feasible. The result is software not properly evaluated, evaluated too late, or not at all; which affects cost, schedule, and performance. A common set of requirements provide the ability to tailor tasks and determine availability and credibility of resources to ensure tasks are adequately covered.

SD Issue 7. Various IV & V implementations within Space Division have become crutches for the software developers. The developers use the IV & V agent as the prime's quality evaluator, relieving the developer of responsibility to properly check the product. This causes agents to be drawn off from true IV & V tasking. Therefore, SD requires better software management practices earlier in the development cycle to avoid this problem. The role of the IV & V agent is to ensure requirements are being met in both the validation role and verification methods. A common set of requirements for the agent would allow enhancement or tailoring of requirements to track a specific development effort. In addition, specific areas are required of the developer to ensure they remain responsible for the final product and interact properly with the agent. SD has addressed their concern by developing the Software IV & V Guidebook. The guidebook covers areas of assessment for various types and critical levels of software based on proposed application. (26:-- ) At this writing, it does not cover incorporation of DOD-STD-2167. A generic set of IV & V requirements in conjunction with DOD-STD-2167 would aid the initial software management improvement issue and an updating of the guidebook later.

AFCMD Issue 8. Numerous software evaluations on a contract require Government action, not contractor action. Air Force Contract Management Division's concern with IV & V implementation is duplication with AFCMD's responsibilities. AFCMD supports and directs Government offices in reviewing contractor's performance and aids program offices in managing the effort. The AFCMD's functions often involve reviewing key documents and recommending specific actions to program offices. AFCMD has found certain of these functions being performed by IV & V agents. This is duplicative and costly, since AFCMD has resources to perform the functions at no additional cost to the Government. Additionally, AFCMD has resources on-site or available within a region to interact

with the developer. This removes the obstacle of conflict of interest and availability of resources between developer and Government. To ensure duplication is avoided, a common set of IV & V requirements coordinated along with the development contract with AFCMD is warranted. The coordination of effort is essential and is commonplace among the chief participants (program office, contracting agencies (AFCMD), potential bidders (development and IV & V), etc.). Therefore, common, coordinated IV & V guidance establishes primary offices' of responsibility's level, depth, and interaction on a contract.

BMO Issue 9. The Ballistic Missile Office IV & V implementation presents a unique concern from the author's perspective. Software IV & V is used extensively to evaluate BMO projects. However, the author's concern is not every project requires extensive IV & V. There are times when a minimum IV & V set is useful, e.g., updating or minor corrections to established programs. Therefore, a common set provides general tasking which may be tailored to fit known corrections and baselines.

#### Category I Requirement

Based on the above issues, the need for a skeleton structure to develop IV & V guidance and requirements is paramount. The structure allows the IV & V proposal to develop during the same period as the software development proposal. Drawing on the initial intent of the Government's development requirements, the IV & V effort will parallel top level tasks. The key is flexibility in establishing the initial steps and allowing future growth or tailoring of contract requirements. The proposed solution for a flexible IV & V structure is listed below.

#### Category I Proposed Solution - Guidance for Software IV & V

To obtain a flexible IV & V structure requires common guidance for IV & V requirements be available. To develop common guidance three assumptions are made. First, each product division will implement software development under DOD-STD-2167, as mandated by HQ AFSC, for all new programs effective March 1986. (25:--) This allows IV & V requirements to be traced directly to the software development. Two, the developer and IV & V agent will interact, by contract declaration, to review the products and other material as specified to the depth specified. Three, in the absence of any direct standard or regulation on software IV & V requirements, guidance is needed to direct IV & V implementation in accordance with DOD-STD-2167. Therefore, the proposed solution is divided between general and specific IV & V guidance. The general guidance covers common areas the

Government should address. The specific guidance is divided into two sections; 1) Specific Guidance and Tasks for Developer and 2) Specific Guidance and Tasks for IV & V agent.

General Guidance. The Government must emphasize in the Request For Proposals (RFP) the objective in establishing requirements, documentation, quality tasks, and IV & V on the project. In the author's view the objective is to produce a common thread of tracking requirements from inception to production, fielding, maintenance, and final retirement. If there are two separate parties, developer and agent, then the RFPs will be separate. RFP coordination is essential at this point. The coordination ensures requirements are accurate and supported by each RFP. The contracts should be written and reviewed by the same evaluation members of the Government to ensure requirements are not conflicting, redundant, or non-existing in one contract but required in the other. Without effective controls the Government loses oversight, developer loses the objective, and the IV & V agent will flounder using older requirements against newer data that may not correlate to test requirements or results.

Tailoring of requirements is expected. However, if tailored requirements are not correlated between development and IV & V contracts, the effects in the above paragraph will surface. Key drivers in tailoring are the operational environment and projected support requirements. Without initial knowledge of these areas tailoring tends to eliminate tasks that support the drivers. If left unchecked tailoring erodes the product development and software integrity. To sacrifice an item for cost and schedule improvements could undermine software performance to the point of unworkable, unsupportable and probably unmanageable system level concerns. (4:39) The end result, in the author's experience, is higher development costs and longer schedules to correct issues that, if tailored properly would have been manageable, not necessarily unavoidable.

Key in any development, especially with multiple contracts, is a common set of terms, and definitions for the project. Along with common terms the Government must establish and understand the main software drivers. Those drivers consist of Computer Software Configuration Items (CSCI) and the related interfaces at the macro level. Without the interfaces and CSCIs, the common thread for the development is harder to establish. The thread provides traceability among the software drivers back to the system or sub-system requirements. In addition, top level software drivers can trace requirements down to actual code level implementations, if low level specifications are required.

It is critical that the agent, Government, and developer understand the thread of continuity for the software. A method to establish continuity is effective application of DOD-STD-2167, MIL-STDs-490, -483, and -1521. The application allows tailoring of documentation, specifications, testing, and reviews. These four standards contain software development and IV & V related efforts. The successful integration of the software tasking achieves the continuity and positive interactions between all participants.

Finally, avoid excessive changes in the developers contract; which differ from the initial requirements in the RFP. Since the objective is parallel contracts, excessive changes require recoordination of tasks between developer and IV & V contracts. One approach is to release the agents RFP during the developer's Best And Final Offer (BAFO). This allows the IV & V RFP to contain a majority of final tasks that support the development effort.

Specific Guidance and Tasks for Developer. The specific guidance a developer must know is that an IV & V agent or activities will be required. This is critical even if the developer and IV & V agent are the same. Without specific guidance, the internal or external teams will not understand responsibilities, limitations, and requirements. This allows the developer to structure the proposal to reflect IV & V related tasks. Those developer related tasks are outlined below.

Developer Specific Tasks. Specific contractual tasks are required to ensure the developer understands the basics of software development and evaluation. The following represents a common set of IV & V related tasks a developer should perform. Without a common set, the interaction between the developer, Government, and IV & V agent is jeopardized.

1. The developer is required to develop and implement a Software Quality Program and document the program in a Software Quality Program Plan (SQPP) or Evaluation Plan (SQEP). The plan contains various IV & V activities. (19:6; 7:9) This brings division of responsibilities between the developer and agent up front. Additionally, the developer is tasked with developing the Software Development Plan (SDP), which documents relationships and interactions with the agent. (18:5,6)

2. The initial documentation required for a project consists of: System Segment Specification (SSS) (6:--), Software Requirements Specification (SRS) (12:--), Interface Requirements Specification (IRS) if numerous interfaces are required (13:--), Software Top Level Design

Document (STLDD) (8:--), Version Description Document (VDD) (9:--), Operational Concept Document (OCD) (11:--), and Software Test Plan (10:--). These documents support basic software engineering practices. In addition the documents support major reviews and control practices established in MIL-STDs-490 (15:--), -483 (14:--), and -1521 (16:--). The documentation is initial insight into the software that the Government and IV & V agent will have to determine if requirements are met.

3. The contractor shall conduct an initial System Design Review (SDR), as outlined by the program office, to initiate the product design and development. Integral to the SDR will be the Software Specification Review (SSR). The purpose is to review essential requirements, establish draft baselines, and coordinate interactions on deliveries, schedules, costs, and other factors determined by the program office. (16:23,31) The reviews do not replace the formal SDR or SSR reviews if required in the remaining contract. The initial review serves to "kick-off" the project effort, establishing common goals and continuity among the participants. This way, if changes are made they are made against an agreed to structure, making contract modifications easier and associated ramifications understood.

This section established an initial set of tasks and procedures for the Government and developer to follow; providing a minimal level of interaction, coordination, and product quality for a project. To complete the common guidance structure, the IV & V agent's tasking is required.

Specific Guidance and Tasks for IV & V Agent. The intent of IV & V effort is to detect problems, errors, and incompatibilities with stated requirements. In addition, the agent should evaluate proposed products, related documentation, and recommended actions to improve the product to meet stated and baselined requirements. Specific guidance for the agent is presented below.

1. The Agent's RFP should contain a Not To Exceed (NTE) threshold that is finalized after the first development review or series of reviews, e.g., System Design Review and Software Specification Review. This is an alternative to the BAFO/RFP release discussed earlier. The advantage to a NTE is the agent can begin work at the same time as the developer, as long as the work does not exceed a specified ceiling. This provides the Government and agent time to specify specifically what tasks are required. This is performed after the first major program review, when structures are established and relationships are agreed to. Therefore, effective coordination between contracts and participants is maintained.



2. The Government needs to exercise caution in selecting the IV & V agent. The possibility exists for legal action if the agent could become a potential second source for the software. This is not always possible. Therefore, early agent establishment will surface probable conflicts of interest. The early indications allow manageable redirection, contract modifications, or reselection of an agent.

3. The agent must provide the types of records and flow of communication required between the Government, developer, and agent. Also, the extent of the agent's participation in formal and informal reviews must be specified. This task is integrated with the records task since reviews usually require documentation and records. (20:5) The depth of the documentation review and records needs establishment. This avoids later confrontations over legal rights and possible conflict of interest as noted under the ASD Issue 2.

4. As the development cycles mature into testing phases, the validation tasks become critical. The verification tasks are still required to ensure documentation adequately reflects the changes, improvements, documented results, trouble reports, and follow-up actions. The validation by the agent is done in an evolutionary fashion. When the developer releases software units the agent may test these lower units to ensure basic integrity of the modules. As the tests progress through units, to components, to CSCIs, and finally to integration tests, the agent is in the loop. The agent performs validation testing, examines test data against expected results, and traces requirement back to governing specifications or documents. The verification and validation is documented in accordance with the established records and procedures. (22:57-64)

5. The IV & V contract should state the requirements for each phase or cycles in the development process, based on the tailoring specifics for the developer.

6. The agent should review, if applicable, the Government OCD and CRLCMP. These outline specific operational and support issues for the software. If the agent will be the supporter (AFLC), it is paramount that they be involved in operational concepts. If not, they may not know support issues or how the system is expected to operate. Without operational and support knowledge, the ability to correct and update software during its lifecycle is limited. (4:55)

The above guidance provides an outline to establish the foundation for IV & V contracting and interactions. The specific tasks for an IV & V contract are outlined below.

IV & V Specific Tasks. The tasks below, in conjunction with the above guidance, establish an initial IV & V effort in parallel with the developer. Tailoring and enhancements of various elements are expected, but in concert with the development contract.

1. The agent must review developer's plans, specifically the Software Development Plan, to ensure it relates to the specific job being performed. This is essential; since as programs progress, design and development must track the plan.

2. During design the agent is tasked to review the applicable SSS (or equivalent), OCD and SRS/IRS documents to ensure proper flow down of requirements. As an example, the agent ensures requirements in the STLDD flow to SRS which flow to the SSS. (8:4,6; 12:9,14; 6:8,18)

3. In conjunction with specification review the agent should review interfaces, ensure their proper flow in requirements, and review new interfaces and CSCIs as they develop. This ensures new requirements are not inadvertently introduced by changes. This is known as requirements creep in the acquisition field and is watched closely to ensure software at the end meets the established requirements.

4. The IV & V agent must describe organizational structures and relationships for the agent's team. This includes basic agreements on exchange of data with the software developer. Additionally, an expected list of resources required to perform the IV & V tasks is developed. (4:81) This factor includes the personnel, facilities, environments, Government related data, facilities, software, and equipment required or expected. (20:4) The agent delivers the information in a Software IV & V Plan, similar to the SDP structure, but in contractor format. This is an option until a formal IV & V plan for software is approved.

5. The agent requires a copy of the VDD to ensure versions being developed and matured by the developer are properly utilized in the noted fashions. Additionally, the agent needs to develop specific documentation, in the form of an SDP and test plans, documenting how the agent will do software development and testing as applicable.

6. The agent must prepare to attend the first two project reviews, e.g., SDR, SSR. Before attending the reviews, the agent presents inputs about the developer's project to the Government for consideration. The inputs are based on documents reviewed and requirements outlined in MIL-STD-1521. (16:23,31)

## Summary

The Category I solution provides the product divisions the means to improve IV & V implementations. The solution addresses three areas; General, Developer, and IV & V Guidance. These areas are applicable to the Government, software developer, and IV & V agent. Without a coordinated effort among the participants, the IV & V effort becomes a cost and schedule hindrance or a useless tool. With a coordinated approach, IV & V supports the software development effort.

## CATEGORY II DATA COLLECTION AND ADVOCACY

Category II concerns software issues involving collecting data and maintaining advocacy for software IV & V across Air Force Systems Command. The issues that produced this category were derived from four sources; ESD, SD, AD, and AFLC; as summarized in Table 1. The following presents each issue, its relationship to the category and a proposed solution for the Category II concerns.

### Product Division Issues

The issues derived from the product divisions are not restricted to the divisions themselves. Their concerns, in the authors view, echo a basic theme across AFSC. Without backing from headquarters, the field can not always do what is right, especially in terms of cost and schedules. The field does not need additional oversight, but an avenue to share ideas and experiences. This allows direction and policy formulation to evolve outside of a vacuum. Therefore, the following information presents the issues which establish Category II.

ESD Issue 6. The ESD issue suggests a survey be employed to monitor the effectiveness of their implementation of an "on-call" IV & V agent. The survey would provide data for judging the positive and negative aspects of the agents work. Since the "on-call" agent is a new approach, the effort's true value is unknown. The value could effect ESD efforts only or be applicable for other AFSC product divisions. Without data, the effectiveness of the program and possible corrections or improvements applicable for other divisions is unknown.

AFSCMD Issue 6.1. Air Force Contract Management Division's concern parallels that of ESD's Issue 6. A survey would provide data on current IV & V implementations. The data supports identification of potential problems and solutions.

Also, the survey supports AFCMD Issue 8, concerning the establishment of contractual responsibilities and avoiding duplication of efforts. The survey provides visibility of program's early objectives and inter-relationships among major participants.

AFLC Issue 6.2. Air Force Logistics Command is developing a survey to address AFLC IV & V issues for software. However, the usefulness of the data is applicable to AFSC programs and supports AFSC Issues 6 and 6.1. The AFLC office heading this effort provides additional assistance to the computer resource office at HQ AFSC under the Joint Logistics Commanders' working groups. (33:--) The exchange of information from surveys would provide valuable data to both commands, especially since AFLC is not normally involved in early phases of AFSC projects. After AFSC turns the projects over to AFLC, AFSC is removed from day to day project support and field corrections. Therefore, an exchange of data would provide both commands the opportunity to review IV & V data and evaluate effectiveness, policy options, and common IV & V practices.

SD Issue 7. Space Division expressed concern that software developers were using the IV & V agent as their own quality evaluation function. This relieved the developer from doing the required evaluations, which cost time and money. Thus, the product was delivered on time, but often with errors which required more time and money to fix. The SD issue seeks to improve the software management interface. This issue was discussed under Category I for ways to improve the interface. However, HQ AFSC awareness of these potential conflicts is paramount, since budgets, schedules, and performance are their prime concern. Therefore, a survey collecting and a central office monitoring relevant IV & V data could support the awareness. This provides initial visibility to ensure policies are effective and guidance supports contractual requirements under Category I.

AD Issue 10. Armament Division's concern is that, without a strong advocate for IV & V early in a programs life, IV & V for software would be overlooked. When problems do surface with the software, during preliminary and/or operational testing, IV & V type tasking is initiated to find the errors. At this point software and hardware are integrated to a high degree and any changes may adversely effect the performance, causing additional schedule and cost impacts. (4:39) Software IV & V provides an avenue to catch errors early before they become integrated within the hardware and system level products. The ability for early detection is achievable if guidance on IV & V implementation (discussed under Category I) and an advocate that supports the early implementation is available. Headquarters AFSC is ideally suited for this

advocate position. Headquarters provides initial direction and requirements to product divisions and associated program offices concerning projects. In addition, the computer resource offices at each product division form a MCCR network that HQ AFSC interacts with. This network provides the first step in maintaining the flow of information, direction, and advocacy for programs.

#### Category II Requirement

The above issues establish the need for feedback and advocacy on IV & V for software. A survey supports the feedback process. Using established networks, the survey can proceed to collect IV & V data without additional manpower. The pinnacle of the network must advocate early use of IV & V to avoid potential problems of catching errors late. Late errors require extensive corrections and adversely effects software and/or system design to some degree. (4:39)

#### Category II Proposed Solution - Four Interacting Tools

There are four tools that could support the issues outlined above. The tools cover specific offices of primary responsibility (OPR), using at their disposal, already established practices and relationships. Also, collecting data serves as a tool using established relationships. Each of these tools are presented below with accompanying rational.

Each tool interacts with the others. They form a collective group of processes that help in establishing IV & V techniques across AFSC. The techniques evaluate effectiveness and seek to improve IV & V concerns before they effect the reliability of a desired system.

Tool 1 - Interaction. The ability to interact between headquarters and product divisions is paramount. With interaction, the ability to evaluate problems, share lessons learned, and track applications is available to all parties. Currently, HQ AFSC/PLR, Mission Critical Computer Resources Directorate, is responsible in establishing the MCCR policy for AFSC, within AFR 800-14. This office coordinates with individuals at each product division called the Computer Resource Focal Point (CRFP). It is the CRFP's responsibility to work with the respective program offices and provide MCCR advice on projects. The CRFP's advice is directed through the Computer Resource Working Groups (CRWG) and development of Computer Resource Life Cycle Management Plans (CRLCMP) for programs. The CRWG and CRLCMP are tasked directly out of AFR 800-14. HQ AFSC/PLR monitors the CRFPs through bi-annual meetings. Therefore, the application of software policy and the effects of the IV & V core requirements is assessable.

Tool 2 - Early Application. Early application of IV & V starts at the headquarters. When a program is initiated, so is the paper work to establish the program baseline, budgets, and schedules. Numerous offices at HQ AFSC review the program documentation and recommend program actions on a AFSC Form 56. HQ AFSC/PLR provides MCCR direction via this form. Areas of interest include typical MCCR documents to be obtained (SRS, SDP, CRLCMP, etc.) and interactions to be performed (CRWG). The PLR office has a unique opportunity to promote IV & V actions for further consideration through this program documentation. Being responsible for MCCR policy and CRFP interactions, the PLR office is prime for advocating IV & V. This way, the product division CRFPs have an avenue to employ the IV & V concepts that have support from headquarters. Using direction from headquarters, the CRFPs and program offices can evaluate the common guidance for and scope of IV & V efforts.

Tool 3 - Data Collection. The software environment is dynamic. New techniques (DOD-STD-2167), languages (Ada), and concepts (artificial intelligence) are advancing the technology that programs employ as they go into the Air Force inventory. The ability to react to new innovations is critical. The time required to incorporate new approaches is often longer than the innovations life. To decrease the time interval requires the Air Force to know when and where to improve each system. To do this, in part, requires sound engineering practices and evaluations. An effective IV & V approach provides a measure, not 100 percent, that a program can perform as required. This measure of success is the first step in integrating new approaches. Without key understanding of the parts of a problem and ability to react to change, new innovations are not integrated in a timely manner. Therefore, current data on the IV & V implementation across AFSC is required to support improved practices.

HQ AFSC/PLR is the prime candidate for OPR to collect the data on IV & V implementation. This office supports and drafts policy changes. It also coordinates with division counter parts and evaluates technology improvements in current and future systems. The structure is in place to collect the data via the CRFPs, bi-annual meetings, and reviews of program and associated documentation. Appendix A represents a survey, developed by the author, which provides the data collection function, allowing the OPR to establish cognizance over the IV & V implementations. The survey serves a secondary function of monitoring improvements to software development and quality areas. The entire software process encompasses development, quality, and IV & V. As improvements to these areas arise, the survey becomes a management tool to better evaluate the implications of new technology. It should not become a

bureaucratic paper exercise, but a critical data point on the application and implementation of key processes. With HQ AFSC/PLR directing the survey, a common focal point is available to evaluate data, present results, and develop recommendations. This is done with the aid of field inputs and field review.

Tool 4 - Follow Up. An effective process has outside feedback for evaluation. To adequately assess the Category I and II applications, a process of evaluation is required. The HQ AFSC Inspector General (IG) serves this unique function. The IG assesses program and other related office functions across AFSC. The IG's purpose for IV & V should be to assess the impact of IV & V applications. These applications cover the utility of having an IV & V agent, use of common requirements, and pay back in producing an effective software product within the cost and schedule constraints. The IG's analysis is an additional data point allowing PLR to assess the usefulness of the IV & V efforts.

#### Summary

The Category II solution addressed the needs of the product divisions to monitor and improve the IV & V structure. The structure involved maintaining sufficient control over the IV & V process. Without up-to-date information on IV & V, the dynamic nature of software development and technologies could adversely effect the software intensive systems. Therefore, an advocate of the process provides guidance and direction to improve IV & V implementations. Using a survey to collect the data, technology insertion assessments, CRFP/program office inputs, and AFSC/IG assessment produces a closed loop solution for Category II. The unique item about the solution is it comes with a structure already in place. The OPR is in existence, MCCR network of CRFPs is working, and the IG is reviewing programs for compliance with established MCCR guidance. The only added feature is the survey, outlined in Appendix A.

#### INTERIM CONCLUSION

This process of common guidance, OPR/CRFPs, surveys, and follow-up evaluations tie the software development process into a workable structure. Categories I and II provide common guidance, data collection, and advocacy avenues. To effectively support the software IV & V, each category addressed key issues and players. In any contractual development, the Government, developer, and IV & V agent have critical functions for effective software development. In addition, to track developments across AFSC requires a network

and feedback to ensure policies and guidance are sufficient. The Category I and II solutions cover these areas. It will cost time in extra man hours and project dollars to implement. But the savings in ability to react faster and provide usable systems having lower error rates is worth the cost. It is estimated that by using IV & V a 5% to 25% cost avoidance is achievable on development contracts. (4:100) The average cost of an intensive IV & V effort is figured at 25% of the respective development effort. (4:100) Therefore, IV & V efforts in a variety of products can pay their own way.



## Chapter Five

### SUMMARY

### CONCLUSIONS

The IV & V implementations across AFSC are varied, in part, to match various products ranging from aircraft, missiles, and electronics, to space systems. In addition, the variance reflects respective experiences. Each IV & V implementation reviewed was in-line with the intent of current direction. New policy or regulations are not required to improve IV & V implementations. By applying a single software development standard (DOD-STD-2167), software IV & V can approach a standard implementation. This implementation should exhibit less variances when a common IV & V structure is integrated with current development practices. However, to ensure a common structure, in conjunction with DOD-STD-2167, feedback and control of IV & V implementations are required.

The structure developed in Chapter Four is the first step in developing a standard IV & V implementation based on DOD-STD-2167. The structure consists of common IV & V guidance and four tools for improving IV & V implementations across Air Force Systems Command. The guidance establishes initial IV & V requirements for a program office. A feedback loop is available through one of four tools; from monitoring IV & V implementations to improving guidance through associated OPRs. This ensures up-to-date inputs are available for the program offices. Additionally, IV & V data from the program offices are available to HQ AFSC.

A common structure permits AFSC to evaluate various IV & V implementations using a common set of criteria. The evaluation is through collection of relevant data using a network of interested participants. The four tools provide the appropriate avenues for collection of the data using the CRFP network, headquarters directorate to correlate and disseminate the data, and the AFSC/IG to review the IV & V impacts. The IV & V evaluations provide the ability to improve the respective policy and implementation activities.

IV & V implementation yields positive results on programs if applied early. (4:4,39;1:2-5) To that end, AFR 800-14 directs the use as early as possible. (4:4,39;1:2-5) The

Joint Logistics Commanders have initiated tasks to develop a guidebook and standards that address IV & V implementation. However, that direction is not yet complete. Therefore, the objective of establishing IV & V early in a program is met through the application of Category I and II solutions.

### IMPLEMENTATION

To apply the solutions mentioned above the following implementation is recommended.

1. HQ AFSC/PLR should coordinate with the CRFPs on the common IV & V structure. They should review the basic contents to ensure applicability to respective product division applications.
2. HQ AFSC/PLR should send the survey, Appendix A, to each CRFP to establish the IV & V information base. In addition, AFSC should coordinate the data base with associated AFLC survey data. Then review both information surveys during the bi-annual CRFP and HQ AFSC/PLR meeting. The result of the review is used to improve IV & V direction. At the next bi-annual meeting IV & V improvements are evaluated. This approach provides a means to examine issues with interested participants. Then the respective focal points and headquarters can develop solutions in conjunction with their program offices. The real-time effect of working solutions with current programs provides real-world solutions to policy development, if required.
3. HQ AFSC/PLR should coordinate with HQ AFSC/CC on how to manage IV & V implementations. This can be accomplished via an AFSC pamphlet. The pamphlet should cover specific tasks and processes for IV & V. In addition, it should discuss how to scope IV & V efforts to match particular projects. This paper can provide the essentials for these two areas.
4. HQ AFSC/IG should initiate a software IV & V special interest item for their program reviews. This provides the IG field unit with direction on how to evaluate software IV & V on programs.
5. HQ AFSC/PLR, through representation on the JLC-JPCG-CRM, should support completion of the guidebook on software IV & V. A companion item is to support and coordinate publication of the software development and quality standards (DOD-STD-2167A and DOD-STD-2168). This avenue allows integration of key elements of the software IV & V guidance, Categories I and II.

### EXPECTED RESULTS

By providing common IV & V guidance, for the variety of AFSC products, a common foundation is established. Since products differ the foundation can grow to fit the individual requirements. The availability of a feedback network allows guidance to support what the field needs. This provides balance between the common guidance, policy, budget, schedule, and performance constraints.

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APPENDIX A

INFORMATION SURVEY

ON

SOFTWARE INDEPENDENT VERIFICATION AND VALIDATION

The following survey is intended to collect data on the usefulness of software Independent Verification and Validation (IV & V) on major programs within Air Force Systems Command. The data will be used to review IV & V direction, problems, improvements, and importance. An analysis will determine if policy direction is adequate or additional guidance should be considered to ensure the proper use of IV & V.

1. Program using IV & V:
2. Lifecycle phase of the program:
3. CRLCMP status and IV & V recommendations:
4. Agencies and contractors involved: (SPD, AFPRO, developer, IV & V agent, OT&E, AFLC, and user)
5. Fiscal year award of developer and IV & V contract(s)/MOA as applicable: (Type of contract awarded for each; Fixed Price, Cost Plus, etc.)
6. Cost of the IV & V or percentage of program cost devoted to IV & V per fiscal year:
7. List applicable software standards, metrics, and direction implemented on the program for both the developer and IV & V agent as applicable:

## APPENDIX A

8. IV & V agent qualifications:
  - a. Experience level of IV & V personnel.
  - b. Number of personnel involved (full and part-time).
9. IV & V agent interaction with the prime developer:
  - a. Level of access to developer's software, associated tools, and environments.
  - b. Directly submitted write-ups.
  - c. Inputs sent to the program office.
  - d. Subcontracted to the prime.
10. List the available guidance which was followed in determining IV & V use: (Headquarters direction, user, support agent, Computer Resource Working Group, etc.)
  - a. Specifics that determined IV & V scope.
  - b. Products required to be submitted by the IV & V agent to the contracting agency (Government or prime developer)
  - c. Software indicators (management and quality) used by the program office.
11. Critical level of the software and system: (safety of flight, weapon reliability, etc.)
12. Software complexity:
  - a. Interrelationships with other computer software in the mission-critical system (air or ground base).
  - b. Number of interrelated Computer Software Configuration Items within the mission-critical system.
  - c. Interface control requirements for the critical system (aircraft, missile, avionics, ground base, etc.).
  - d. Software language(s) employed.



## APPENDIX A

13. Software Verification Actions:
  - a. Number of lines of code inspected (or to be).
  - b. Testing level of CSCs and CSCIs (unit, integration, etc).
  - c. Number and types of documents to be reviewed.
  - d. Number of errors/concerns reported.
  - e. Number of reported errors/concerns fixed and delayed.
14. Software Validation Actions: (if applicable)
  - a. Testing agency or contractor.
  - b. Types of tests performed.
  - c. Level of testing to the system requirements.
  - d. Acceptability of test.
  - e. Additional documents and code reviews performed.
  - f. Number of errors or corrections detected.
  - g. Number of errors/corrections fixed and delayed.
15. What affect did or will the IV & V agent have on the overall software development effort:
16. The interaction with the respective CAS activity. List the functions from above that the CAS activity did or could provide or manage for the Government:
17. Additional areas of interest concerning use or improvements for IV & V implementation: